DYNAMIC TRASPORT ENHACEMENT FOR TIME ELASTIC TRAFFIC WITH TRANSIENTWARE

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Can we solve transport problems (such as congestion control, QoS, etc.) just from 'network' layers without understanding application and scenario specific details of major applications?

If you think so best of luck!

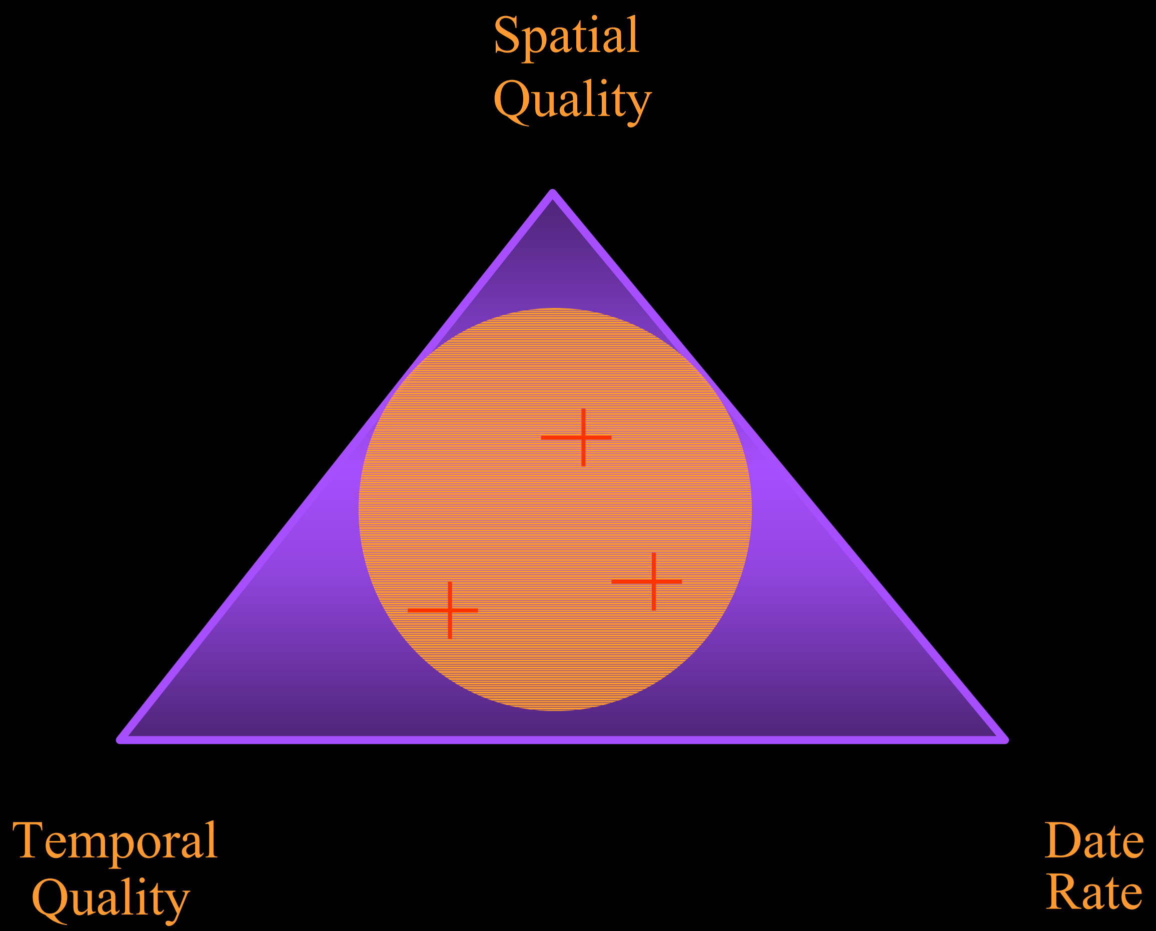
If not perhaps we should design comm. system that can address customer's specific transport needs (the issues are not all quantitative)!

We will consider the case of
Congestion Control for Time Sensitive Elastic Traffic

Elastic Traffic: MPEG-2 Video Transcoding

Principle of Interactivity
An Interactive Comm. Protocol
An Interactive Application
T-ware gluing
Performance

Elastic Traffic:
3 Way Tradeoff in Video

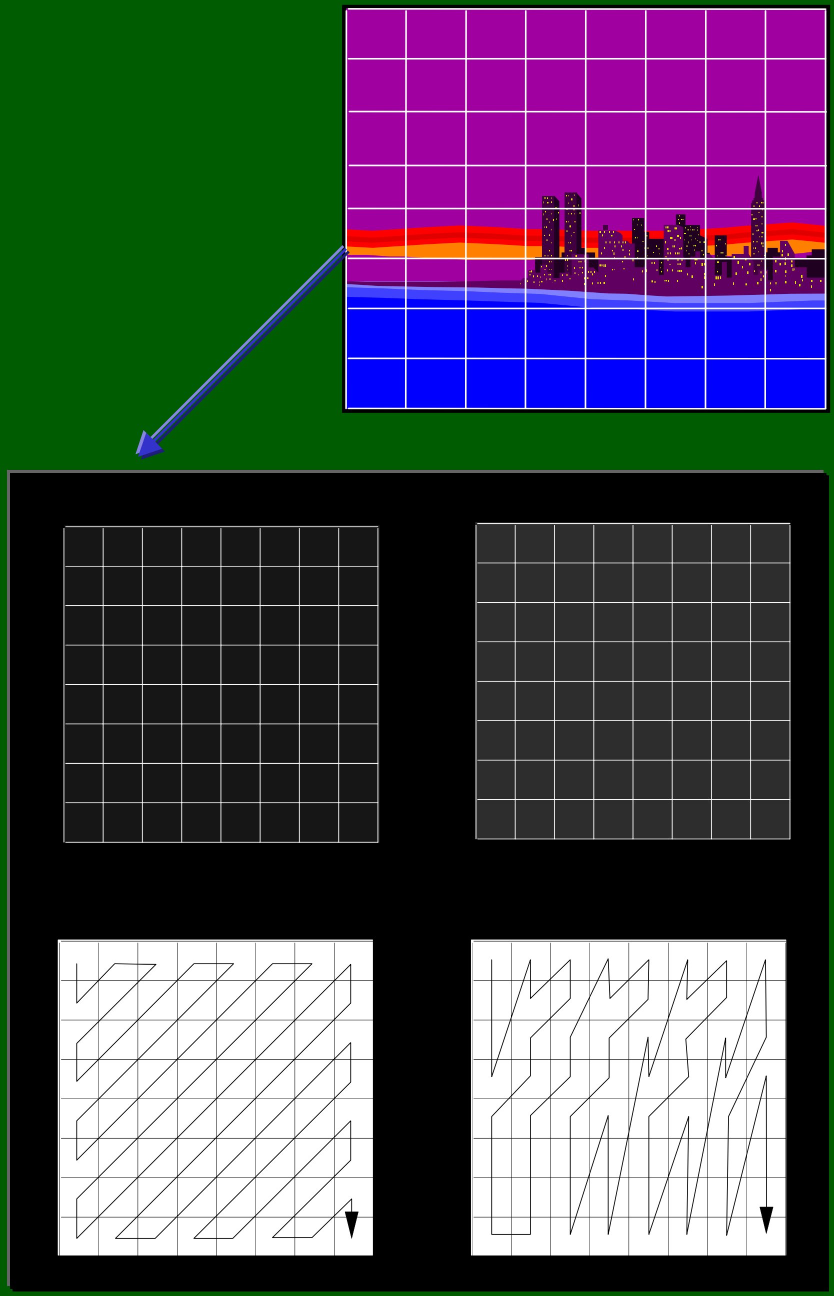


Coding Principles

- Extract Redundancy of Information
  - Spatial (Intra Frame)
  - Temporal (Inter Frame)
  - Phycho-visual
- Offers about 100-200 times compression, but creates long data dependency.

Spatial Redundancy

- 8x8 Blocks
- DCT Transform
- Quantization
- Serialization & Scan
- Run length encoding

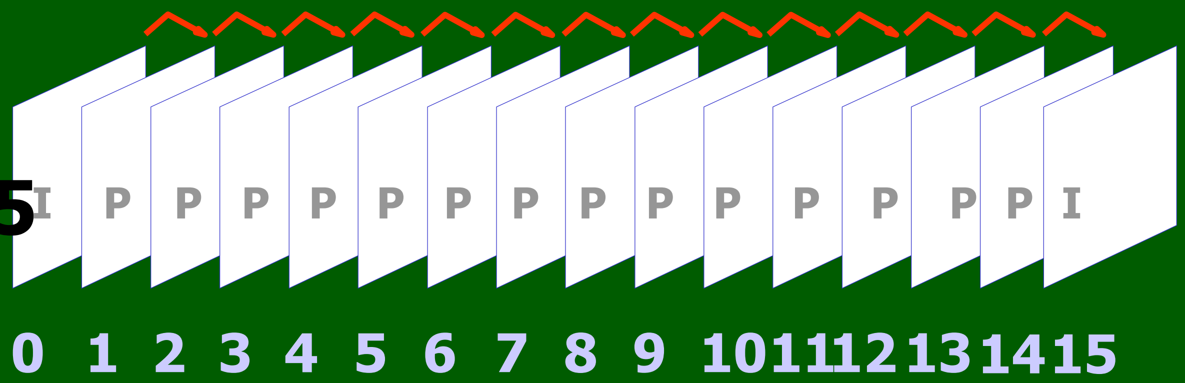


Temporal Redundancy

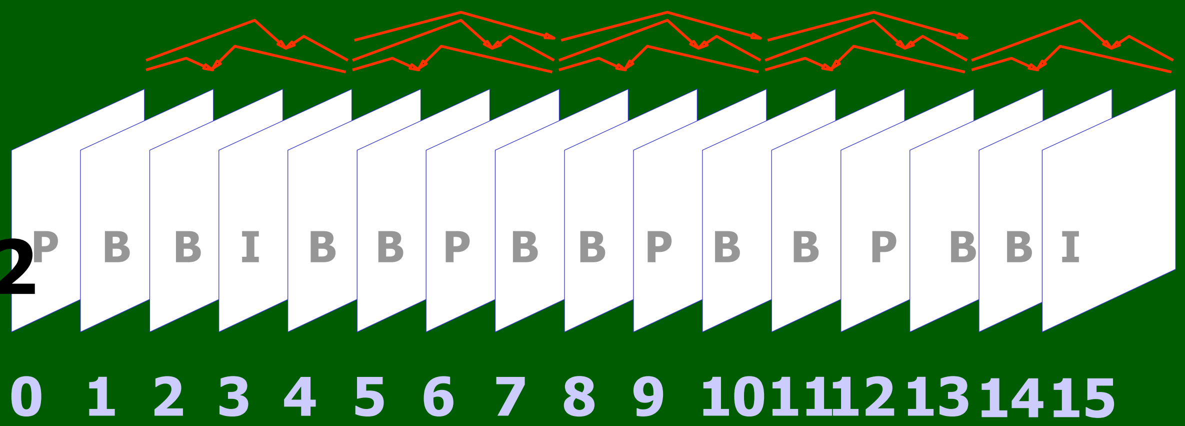
- I, P and B Frames

P(t)=I(t)-I(t-1) B(t)=a.I(t-1)+b.I(t+1)

M=1,N=15

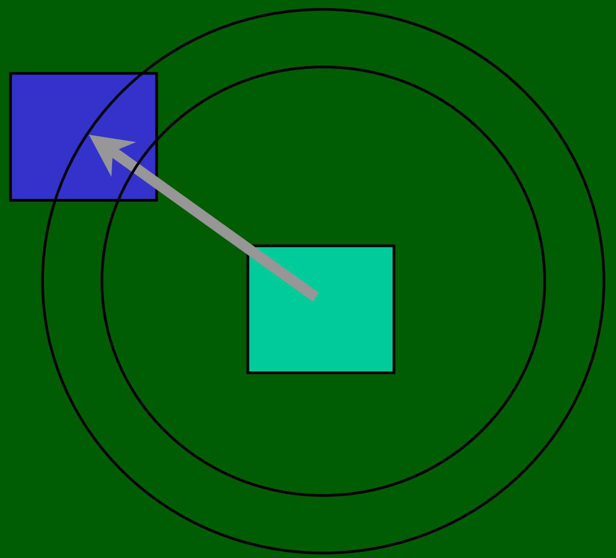


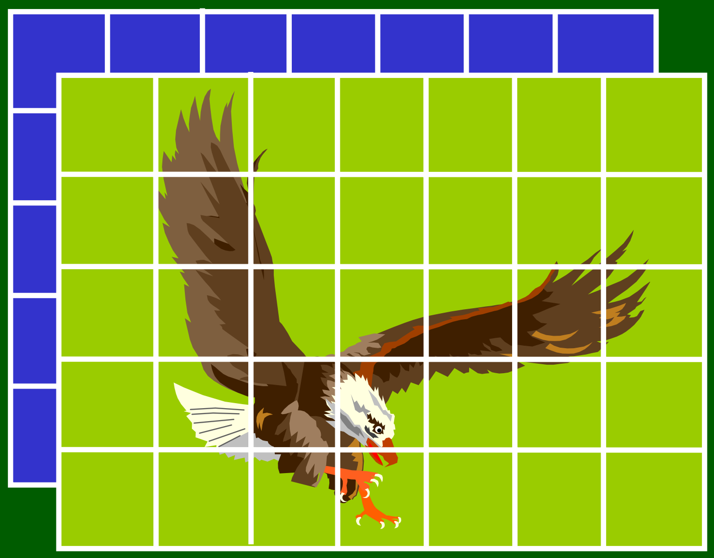
M=3,N=12

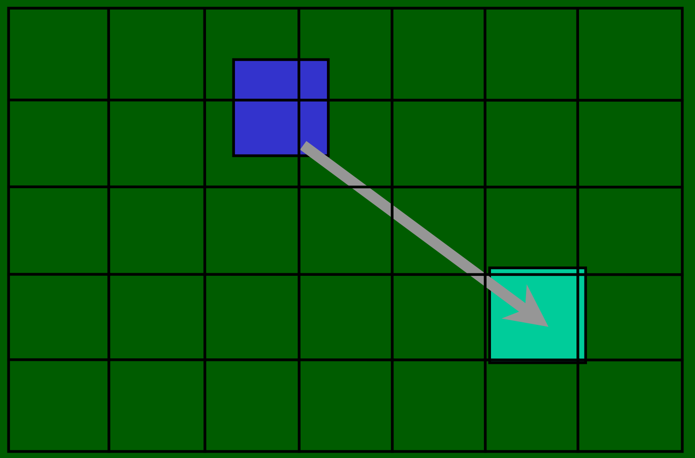


Motion Vectors

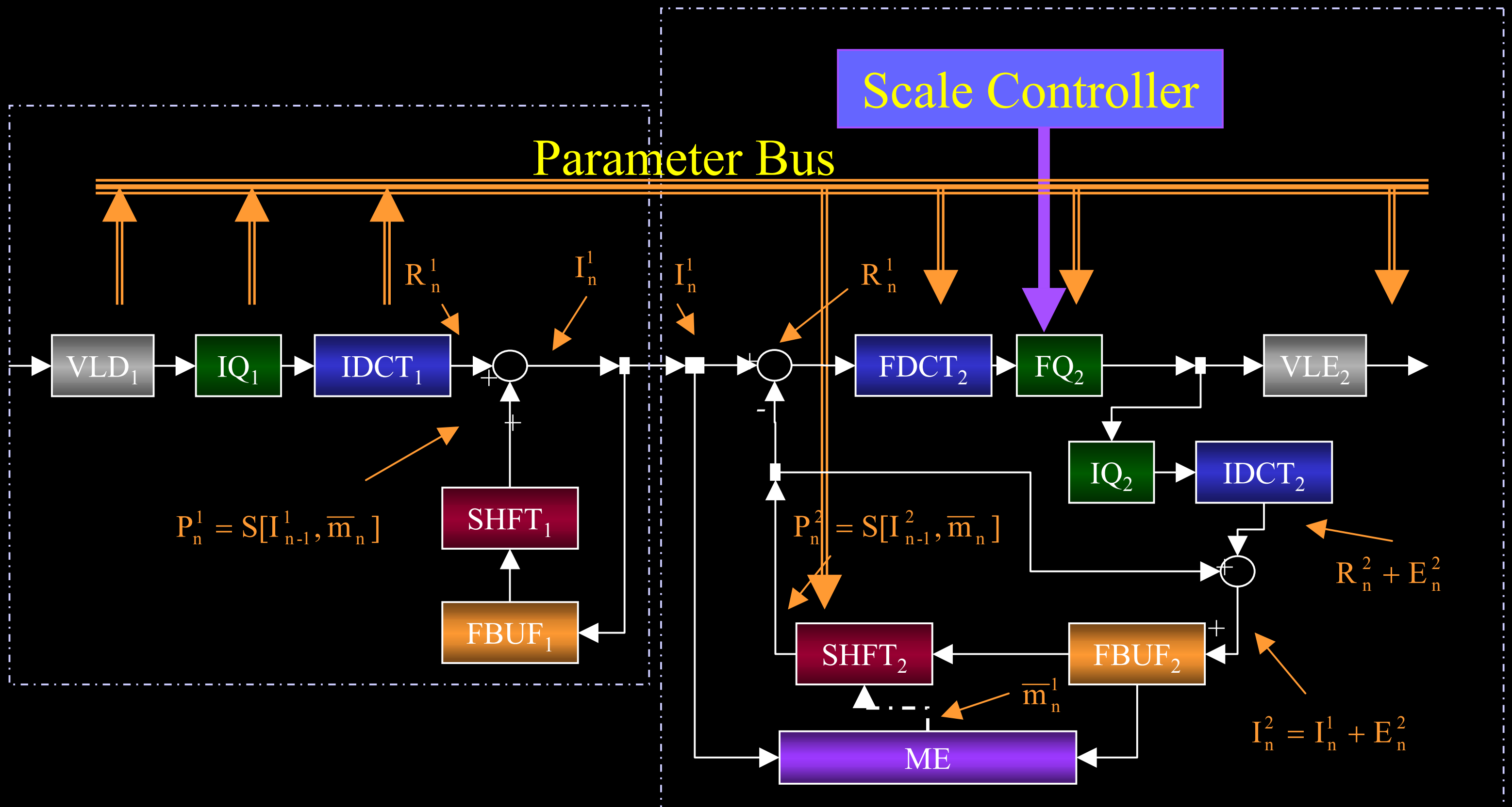
$$P(t,x,y)=I(t,x,y)-I(t-1,x-h,y-w)$$







Full Cascade Adaptation

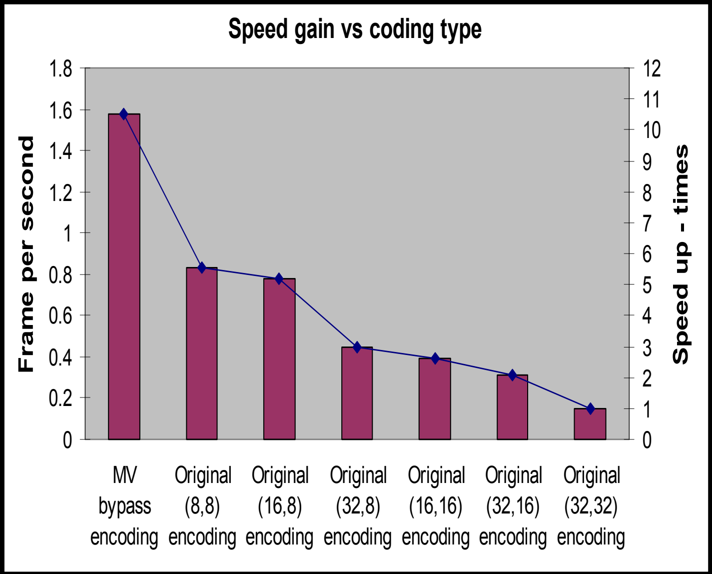


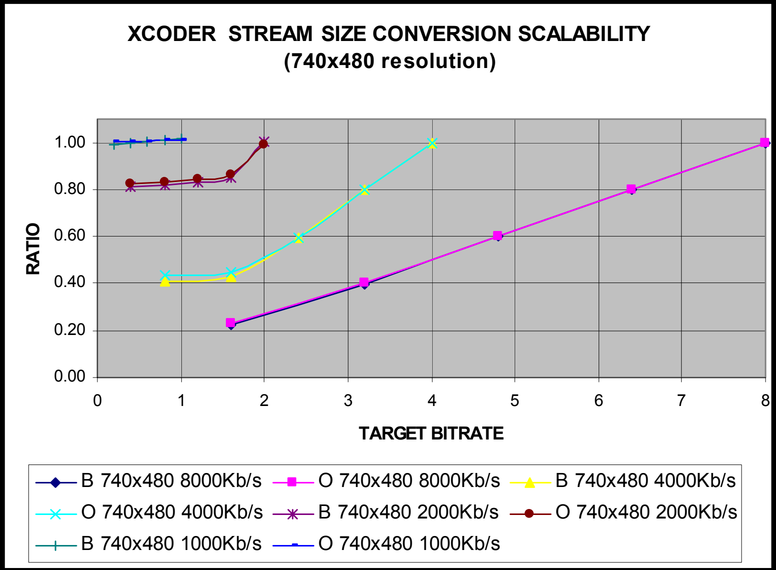
For no picture type conversion:

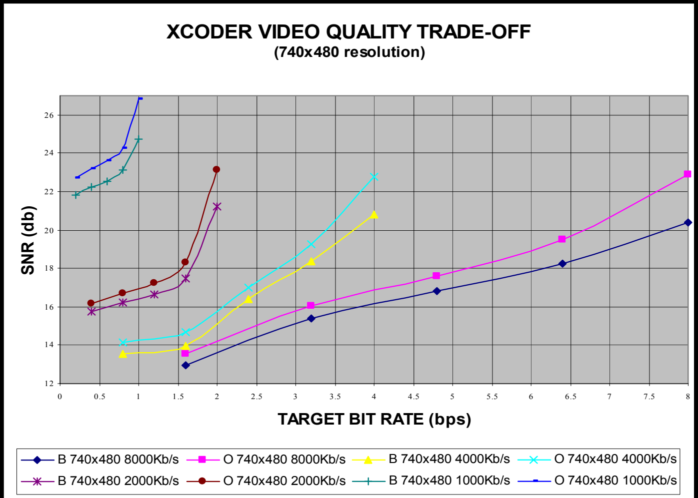
- Bus parameters : macro-block modes (inter/intra decision, forward/ backward interpolation decision), motion-vectors, and picture level features such as

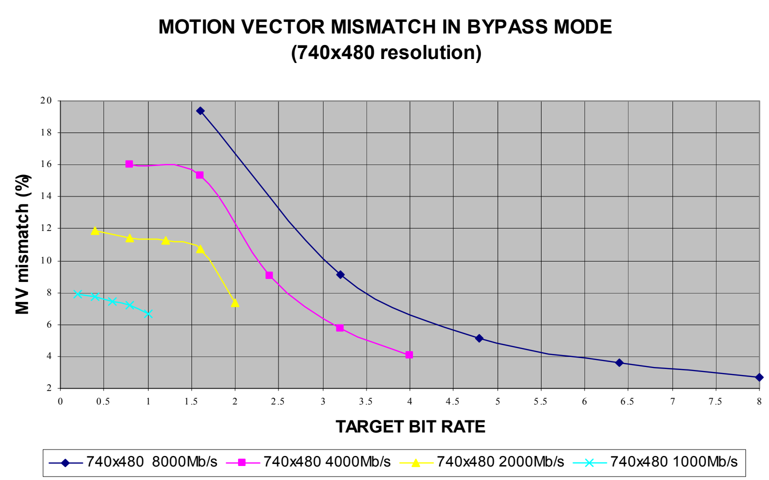
  picture_structure, repeat_first_field, top_filed_first, and prograssive_frame.

3-way Tradeoff









Transport Layer, Application and Congestion

Adaptive Congestion Avoidance

- Primary techniques for congestion control:
  - Drop a packet
    - RED, CHOCK etc.
  - Or Delay them
    - TCP windowing, Admission control, Traffic shaping.
- How suitable are they for time sensitive traffic?
- <u>We decided to experiment with a third principle -- elastic reduction of data by the originator -- the application</u>

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Network Adaptation

- Adaptation fundamentally requires cognizance about environment.
- How do applications adapt in today's network?
- Currently applications do not have any good tool to know about network.
- Unidirectional coupling is mostly by design and lacks formal justification.
  - and of course it is hurting the building of adaptive applications.
- Interactivity by the transport layer is one first step.

The Idea

- Interactivity between "communication service" and "service subscriber".
- Network services to applications:
  - Setup network transport.
    - (some interactivity) If error notify else ready to go.
  - Send or receive data.
  - Close Transport
  - Once communication begins there is no way for applications to know underlying network conditions.
- Current applications at-best can perform end-to-end measurements.
    - Example: RTP feedback, TCP friendly works.

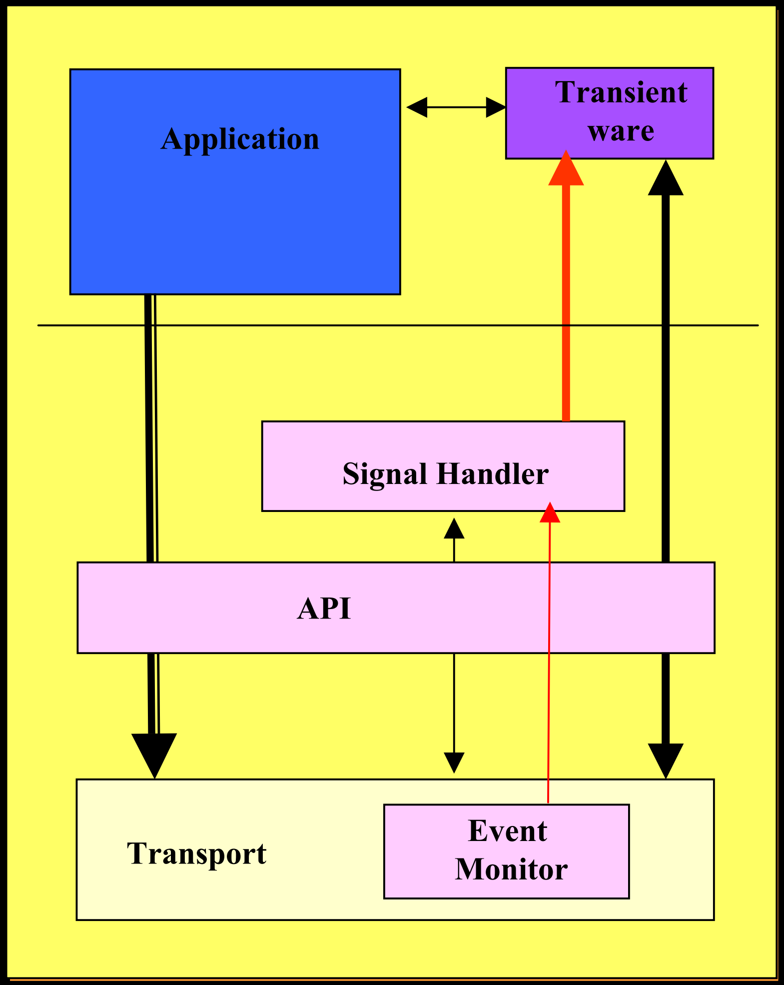
Principle of Interactivity

➢ The interactive scheme has three main features:

- **Event Subscription**
  - Allow the application to subscribe/unsubscribe to specific events.
- **Event Notification:**
  - When subscribed, the end-points should be able to receive interrupt by event handler routines.
- **State Transparency:**
  - An application should be able to read designated status variables in a service protocol.

Gluing Mechanism: Transient-ware

- Transport activated.
- Only activated on event.
- Only modifies application behavior.
- Application programmer of 3rd party designed.
- Disposable & Reusable

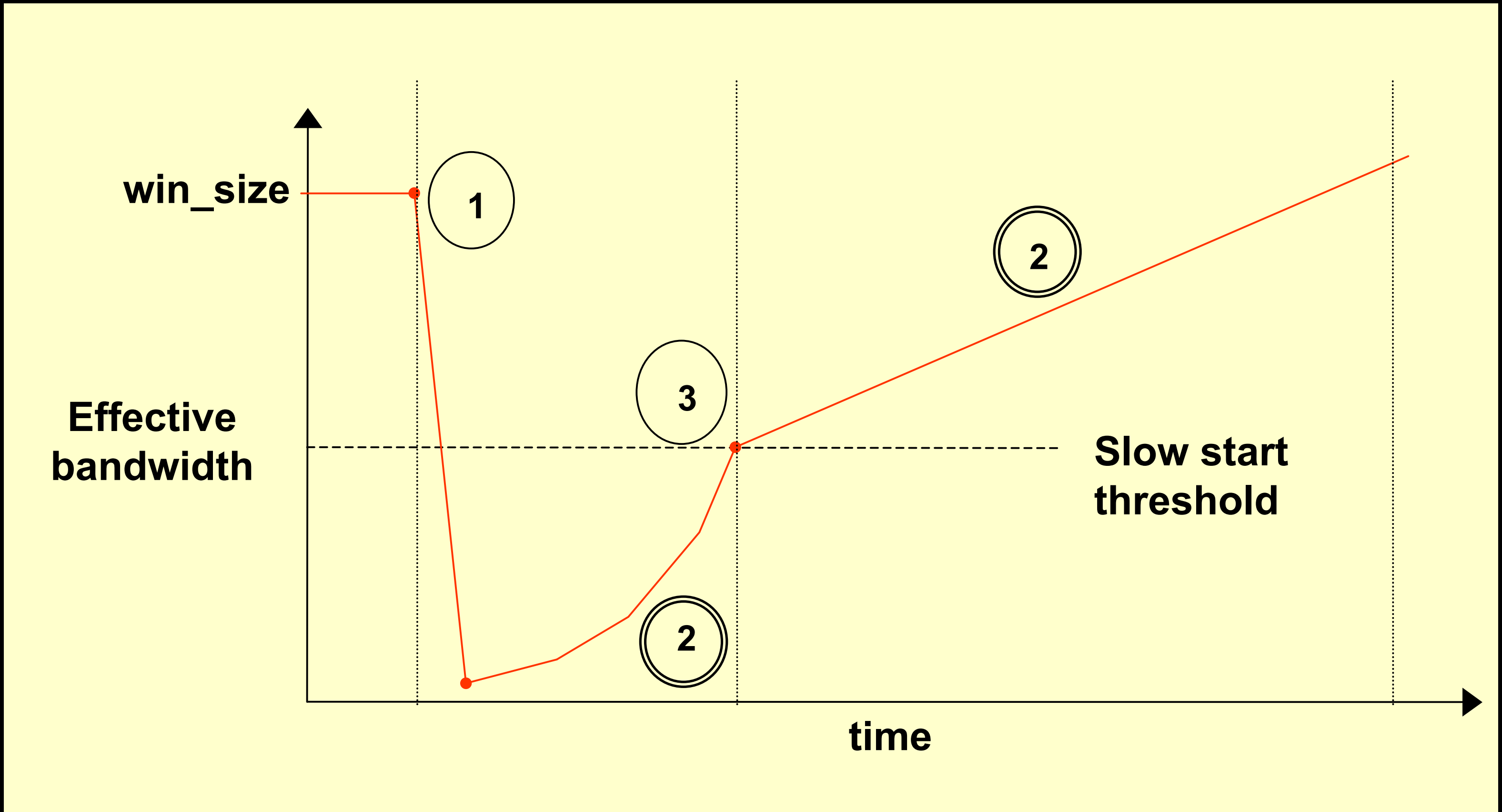


INTERACTIVE TRANSPORT

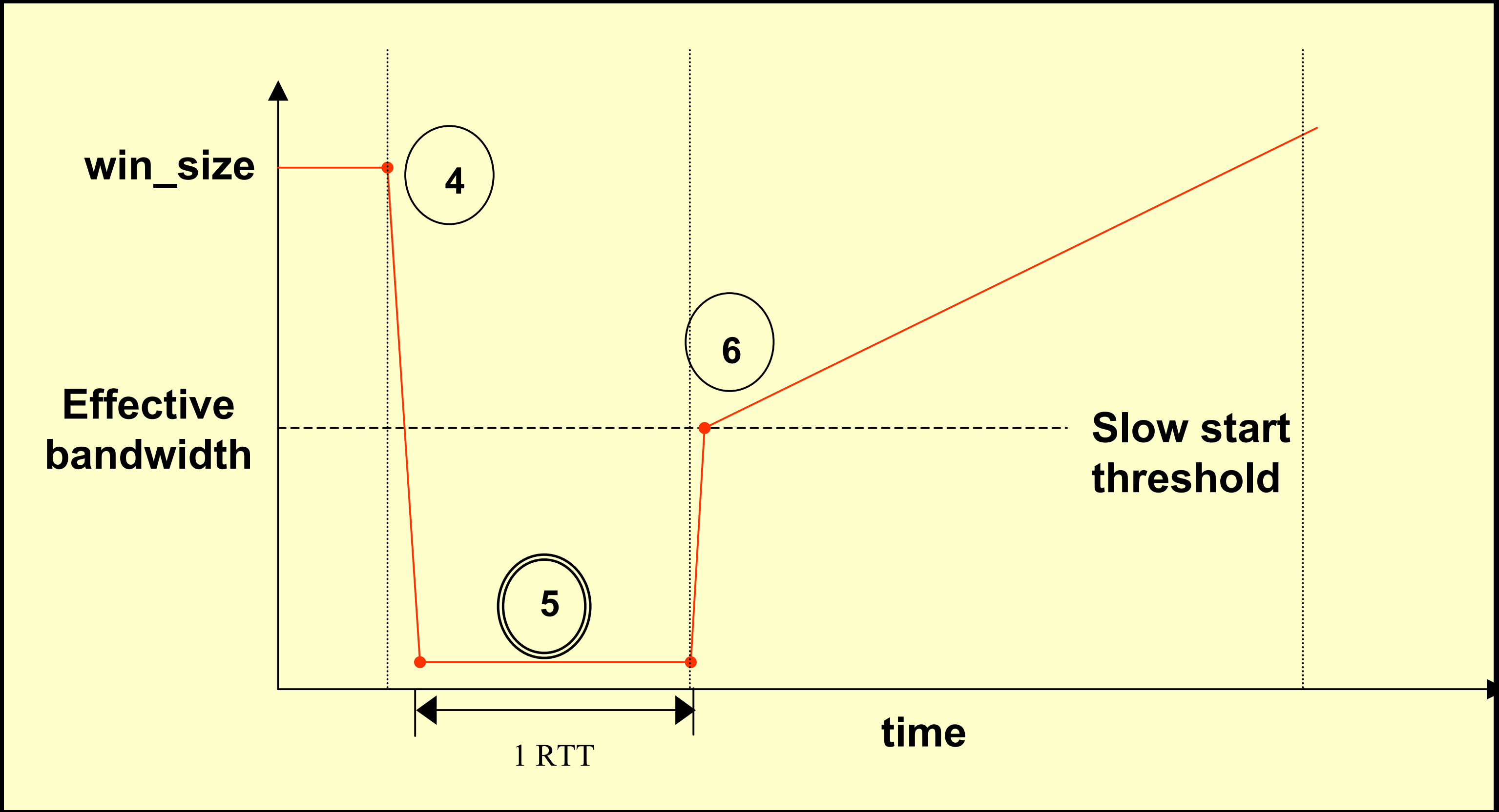
TCP Event Model

- Slow Start & Congestion Avoidance
  - Controls the amount of outstanding data injected into the network.
  - Slow start slowly probes the network to determine its capacity.
- Fast Retransmit & Fast Recovery
  - Detects packet loss using duplicate ACKs.
  - Reduces the congestion window to half its size.

Slow Start / Cong. Avoidance



Fast Retransmit / Fast Recovery



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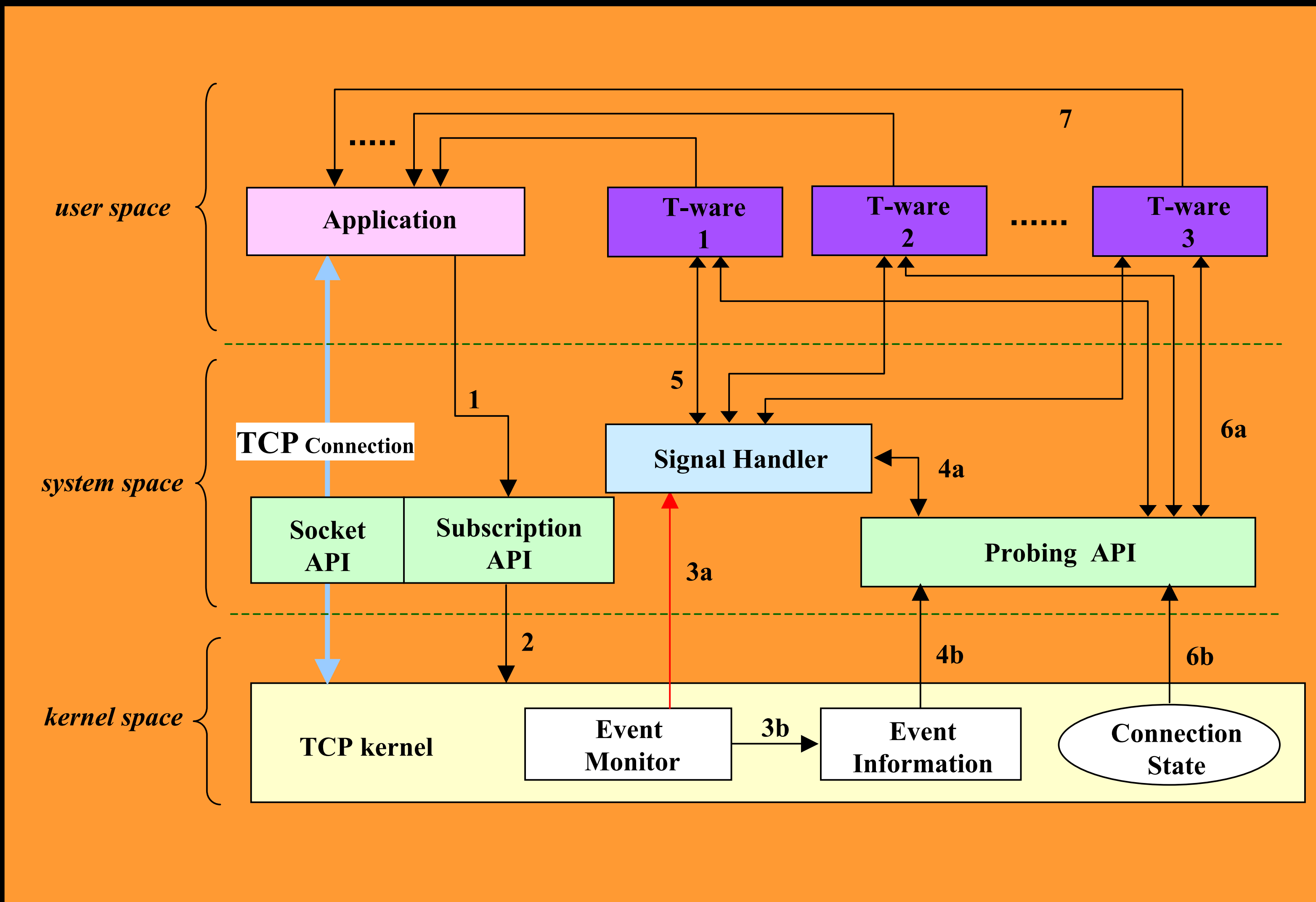
Event Set

Event	Meaning	Description	SS	FR	Sub
1	Retransmission timer timed out	A segment was probably lost	X		X
2	A new ACK was received	Increment `snd_cwnd` either exponentially (if less than `sstheresh`) or linearly	X		
3	`snd_cwnd` has reached the slow start threshold `ssthresh`	Switch incrementing `snd_cwnd` from exponential to linear	X		
4	A third duplicate ACK was received	A segment was probably lost		X	X
5	A fourth (or more) duplicate ACK was received	One segment has left the network; we can transmit a new segment.		X	
6	A new ACK was received	Retransmitted segment has arrived and all out of order segments buffered at the receiver are acknowledged.		X	X

T-ware Extension of TCP



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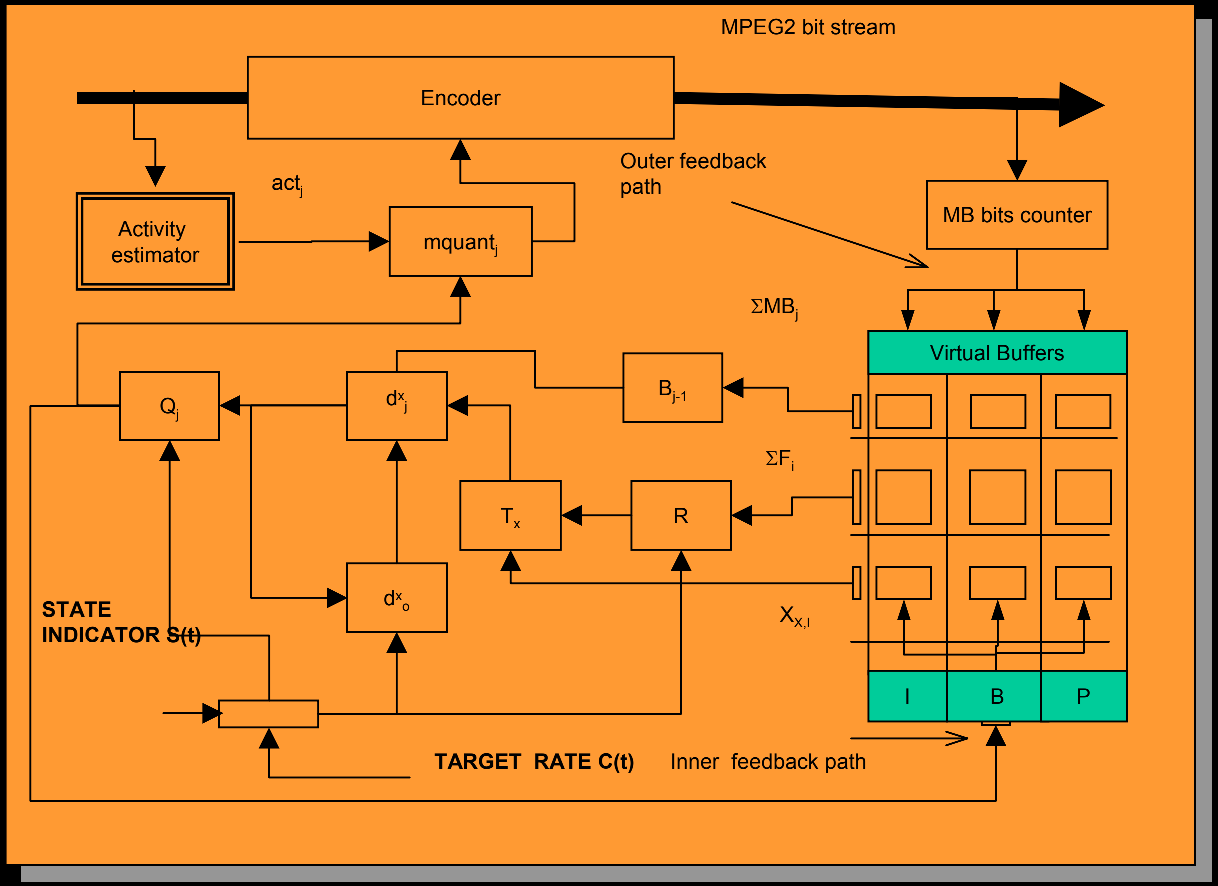
MPEG-2
RATE CONTROL

MPEG2 Rate Control



- TM-5 Model
  - GOP wise CBR
  - CBR with carry
- CBR with carry holdover.
  - In carry forward mode bit saving is saved and added at future GOP.

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Bit-Budgeting in Macroblocks

- Undershoot/Overshoot Estimate
  - During frugal state the carryover is counted but is not applied.

$$e_j^x = d_j^x - d_0^x \cdot S(t)$$

$$d_j^x = d_0^x + B_{j-1} - \frac{(j-1)\cdot T^x(t)}{mb\_count}$$

  - Initial values:

$$d_0^I = 10 \times \frac{r}{31}, \quad d_0^P = k_P \cdot d_0^I, \quad and \quad d_0^B = k_B \cdot d_0^I$$

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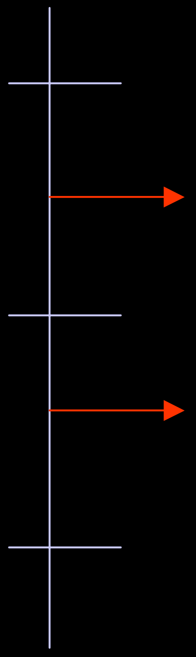
Quantization Model

- Sample Quantization

$$y = \frac{f(x, quant\_step) + .75 \times mquant}{2 \times mquant}$$

$$y = \frac{16 \times f(x, quant\_step)}{mquant}$$



- Quantization factor

$$mquant_j = Q_j \times N\_act_j$$

$$\mathrm{Q_j} = \left[\frac{31 \times e_j^x}{r} \right]$$

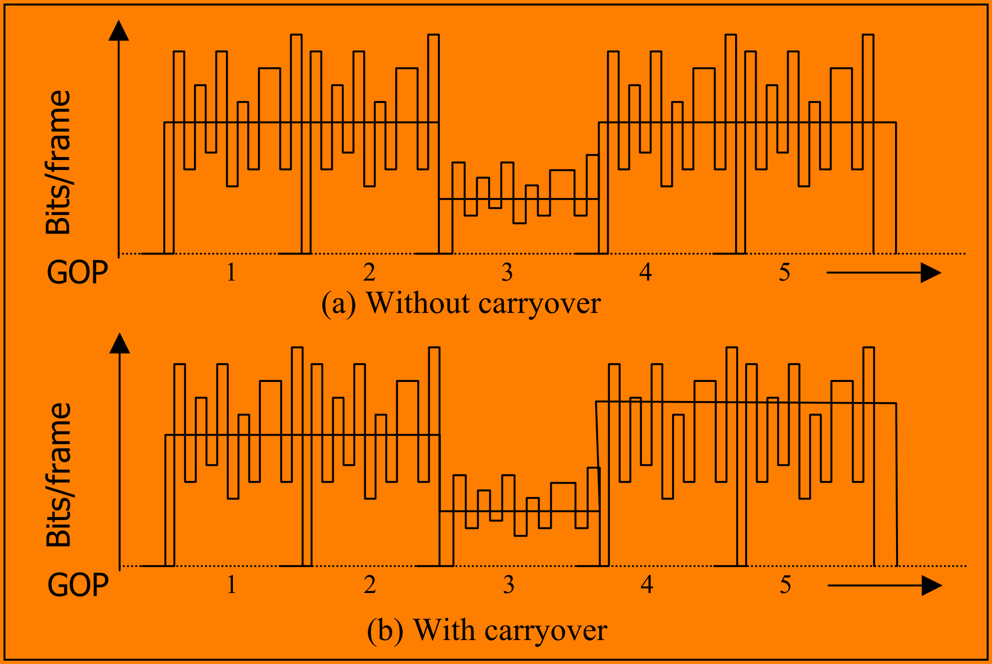
Bit Allocation in Frames

- At the beginning of each GOP a GOP budget is estimated.

$$R_{GOP} = \left\lfloor \frac{(1 + n_{P-remaining} + n_{B-remaining}) \times c(t)}{frame\_rate} + 0.5 \right\rfloor$$

- Then with encoding of each frame the frame type specific frame budget is estimated.

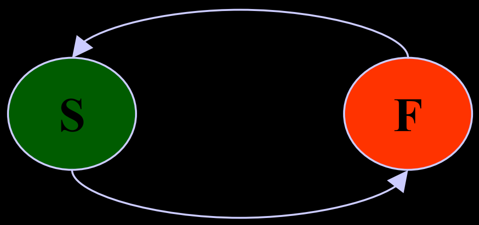
$$T^I(t) = \left\lfloor \frac{R(t)}{1 + \frac{n_P \cdot X_P}{k_P \cdot X_I} + \frac{n_B \cdot X_B}{k_B \cdot X_I}} + 0.5 \right\rfloor \quad T^P(t) = \left\lfloor \frac{R(t)}{n_P + \frac{n_B \cdot k_P \cdot X_B}{k_B \cdot X_P}} + 0.5 \right\rfloor \quad T^B(t) = \left\lfloor \frac{R(t)}{n_B + \frac{n_P \cdot k_B \cdot X_P}{k_P \cdot X_B}} + 0.5 \right\rfloor$$


Bits/frame
GOP
1
2
3
4
5
(a) Without carryover
Bits/frame
GOP
1
2
3
4
5
(b) With carryover

SYMBIOSIS
T-ware

T-ware Symbiosis Model

- Bi-state rate control
  - Bandwidth satisfied state.
  - Frugal state.



- Satisfied state rate:
  - Piecewise per GOP CBR
- Rate retraction ratio:
  - Ratio of frugal state to satisfied state generation rates.

$$\rho = \frac{C_{\min}}{C_{\max}}$$

Frugal State Generation Rate

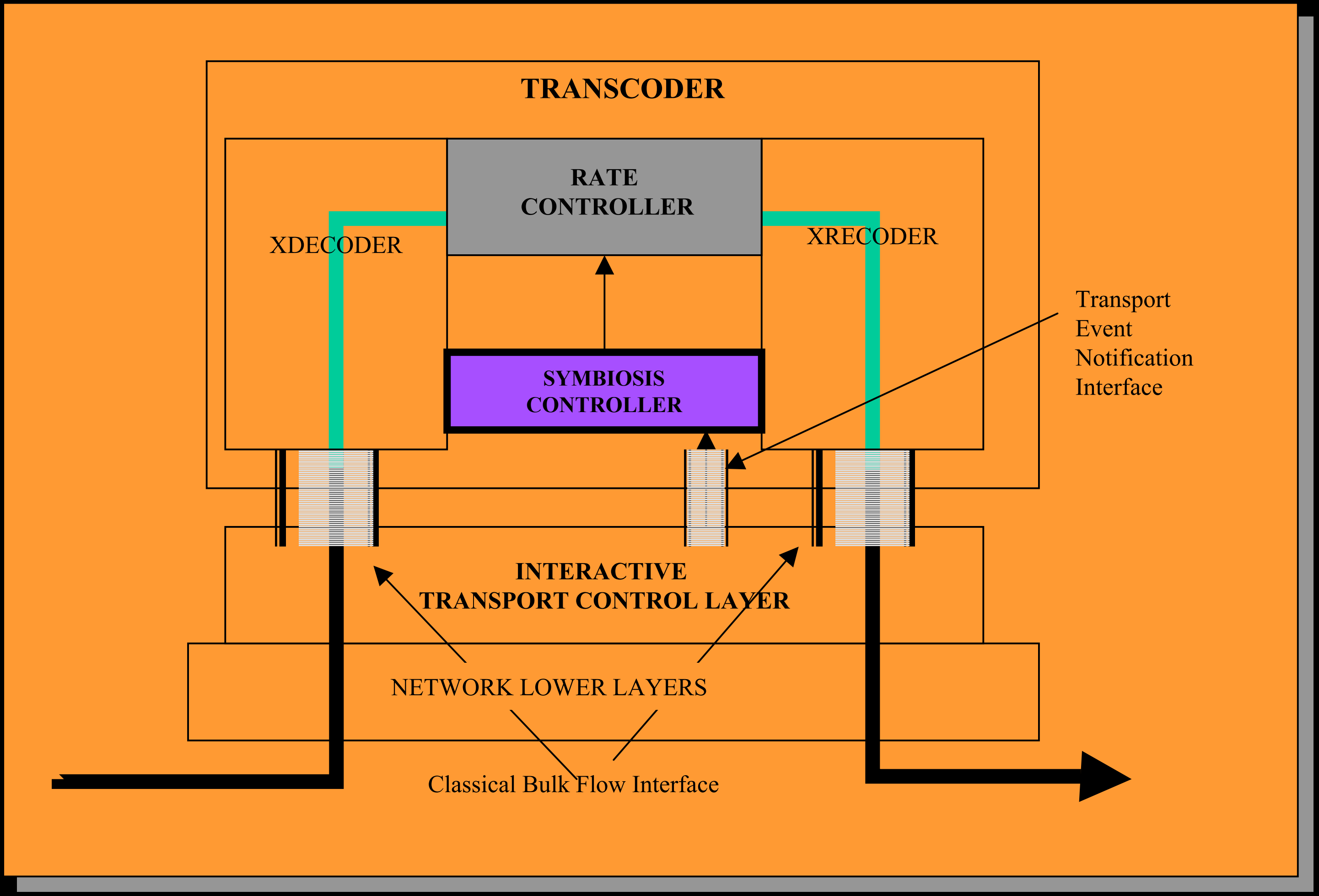
- Backoff to Frugal State Limit

$$c(t) = \rho \cdot c_{\max} \; when \; \xi = 1$$
$$= 2 \cdot c(t-1) \; when \; c(t) \geq \frac{1}{2} c_T(t-1)$$
$$= \min[C_{\max}, c(t-1)+1] \; when \; c(t-1) \geq c_T(t-1)$$

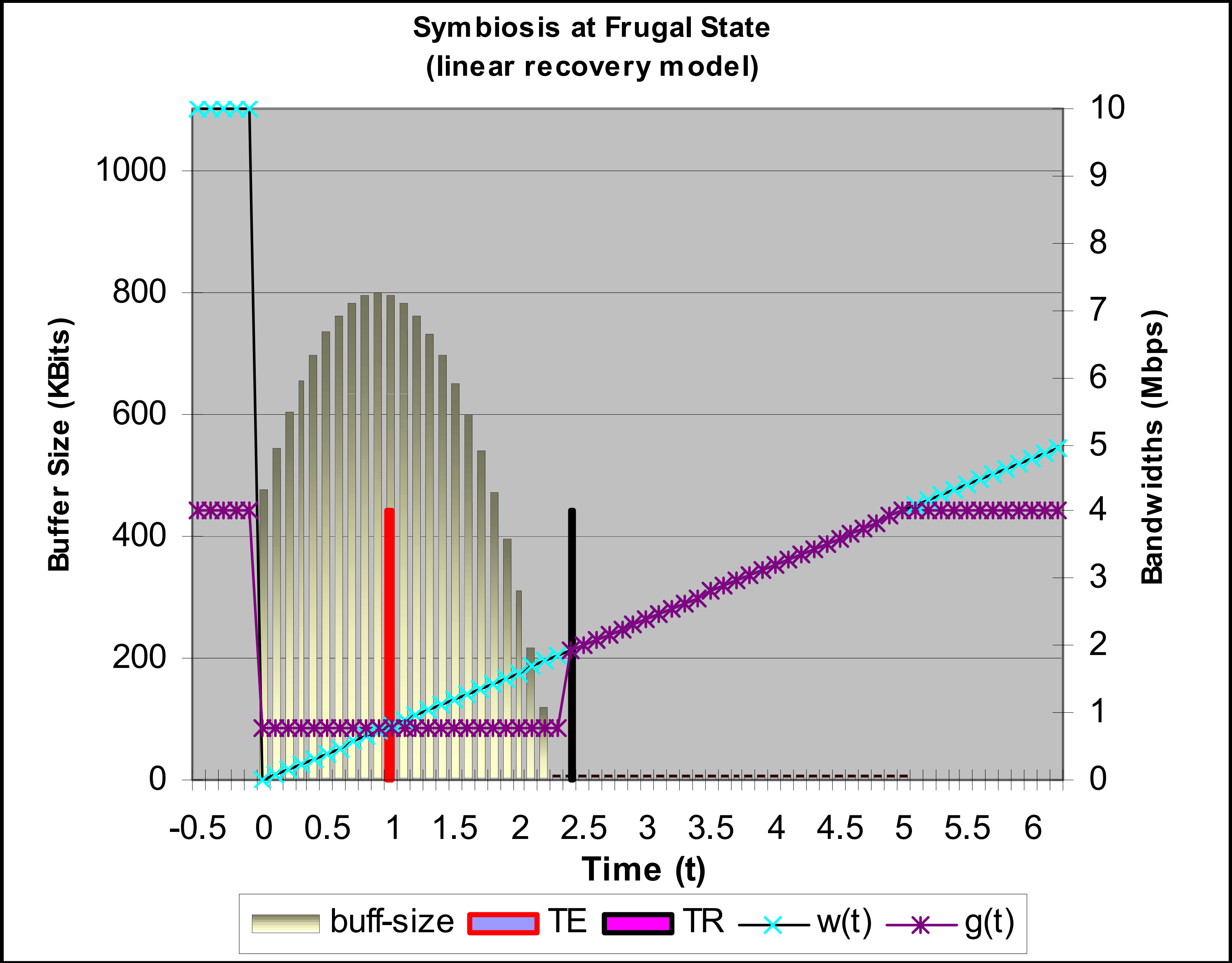
- Fast Recovery and Slow Start

$$c_T(t) = \frac{1}{2} c(t-1) \; when \; \xi = 1$$
$$= c_T(t-1) \; otherwise$$

Overview

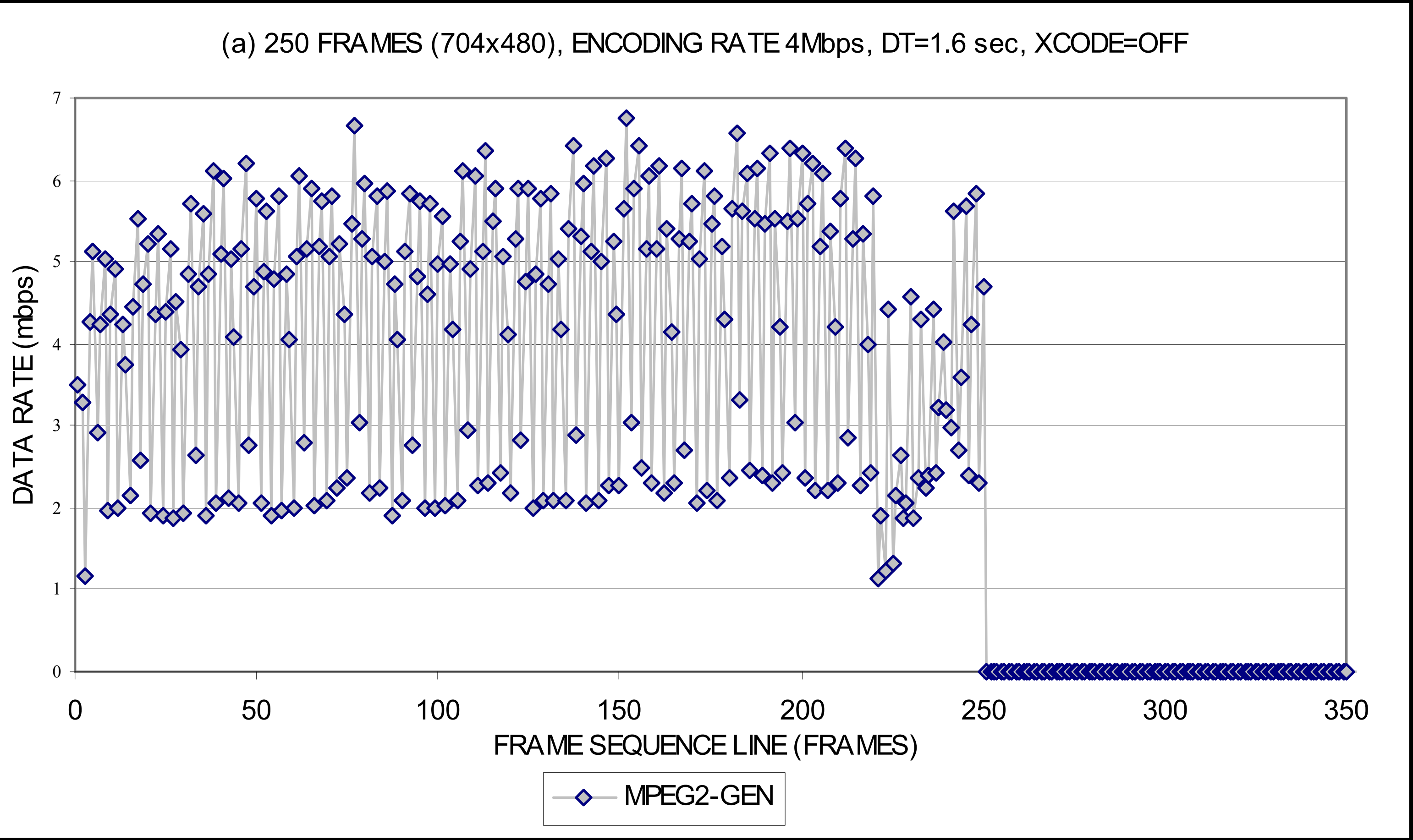


TRANSCODER
RATE CONTROLLER
XDECODER
XRECODER
SYMBIOSIS CONTROLLER
Transport Event Notification Interface
INTERACTIVE TRANSPORT CONTROL LAYER
NETWORK LOWER LAYERS
Classical Bulk Flow Interface


Symbiosis at Frugal State
(linear recovery model)
Buffer Size (KBits)
0
200
400
600
800
1000
Bandwidths (Mbps)
0
1
2
3
4
5
6
7
8
9
10
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
Time (t)
buff-size
TE
TR
w(t)
g(t)

PERFORMANCE

MPEG2 Transport Level Performance (generation)



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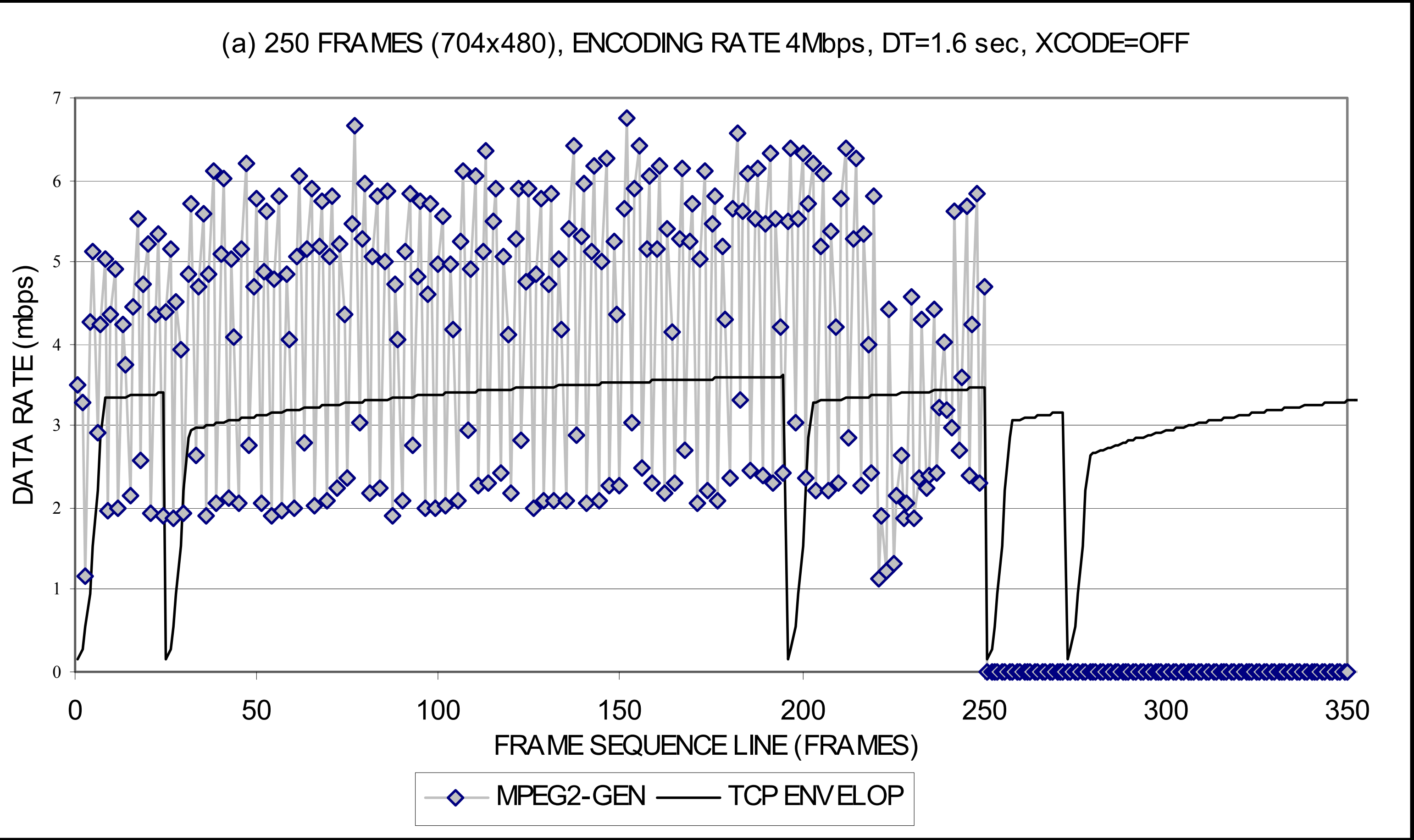
MPEG2 Transport Level Performance (Events)



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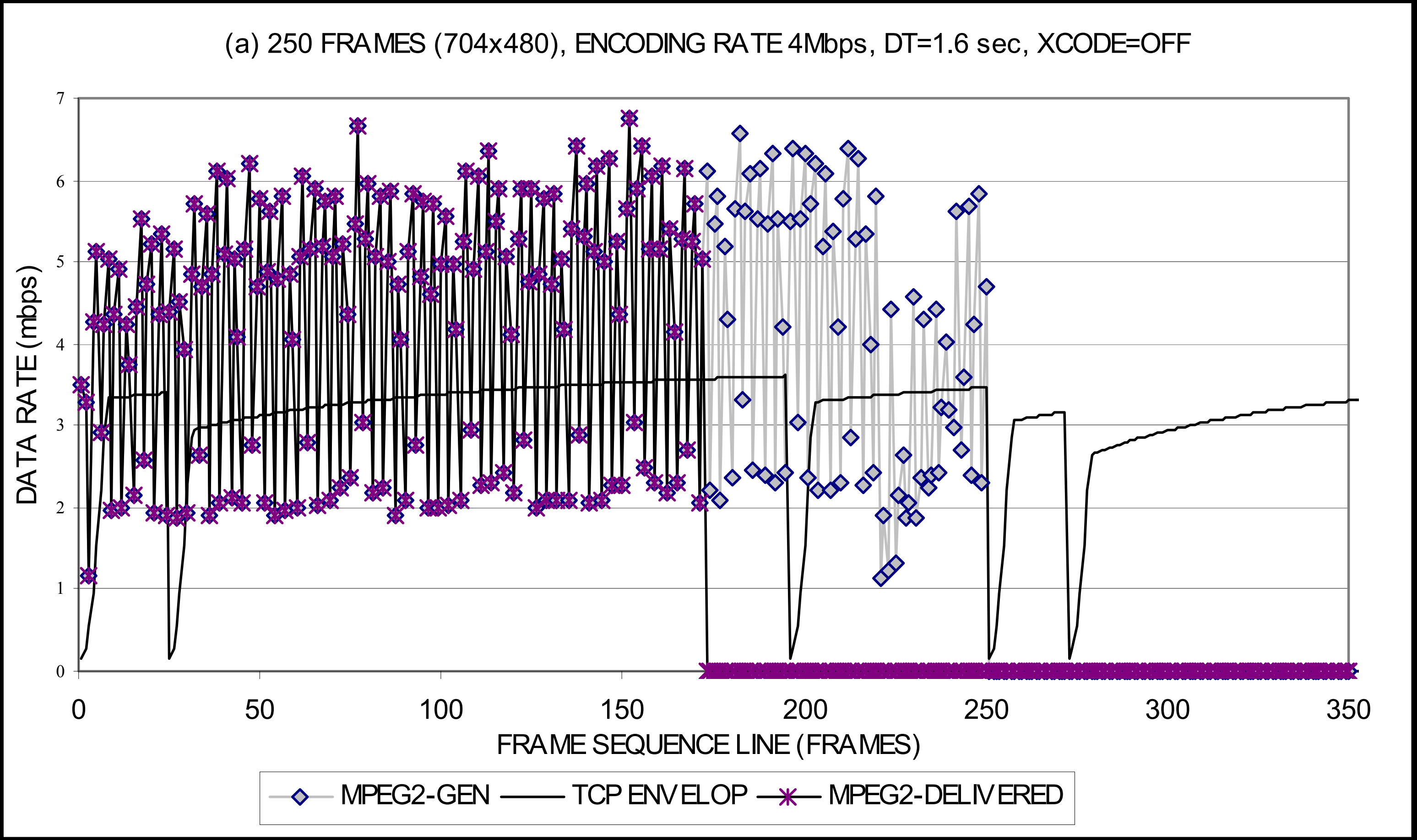
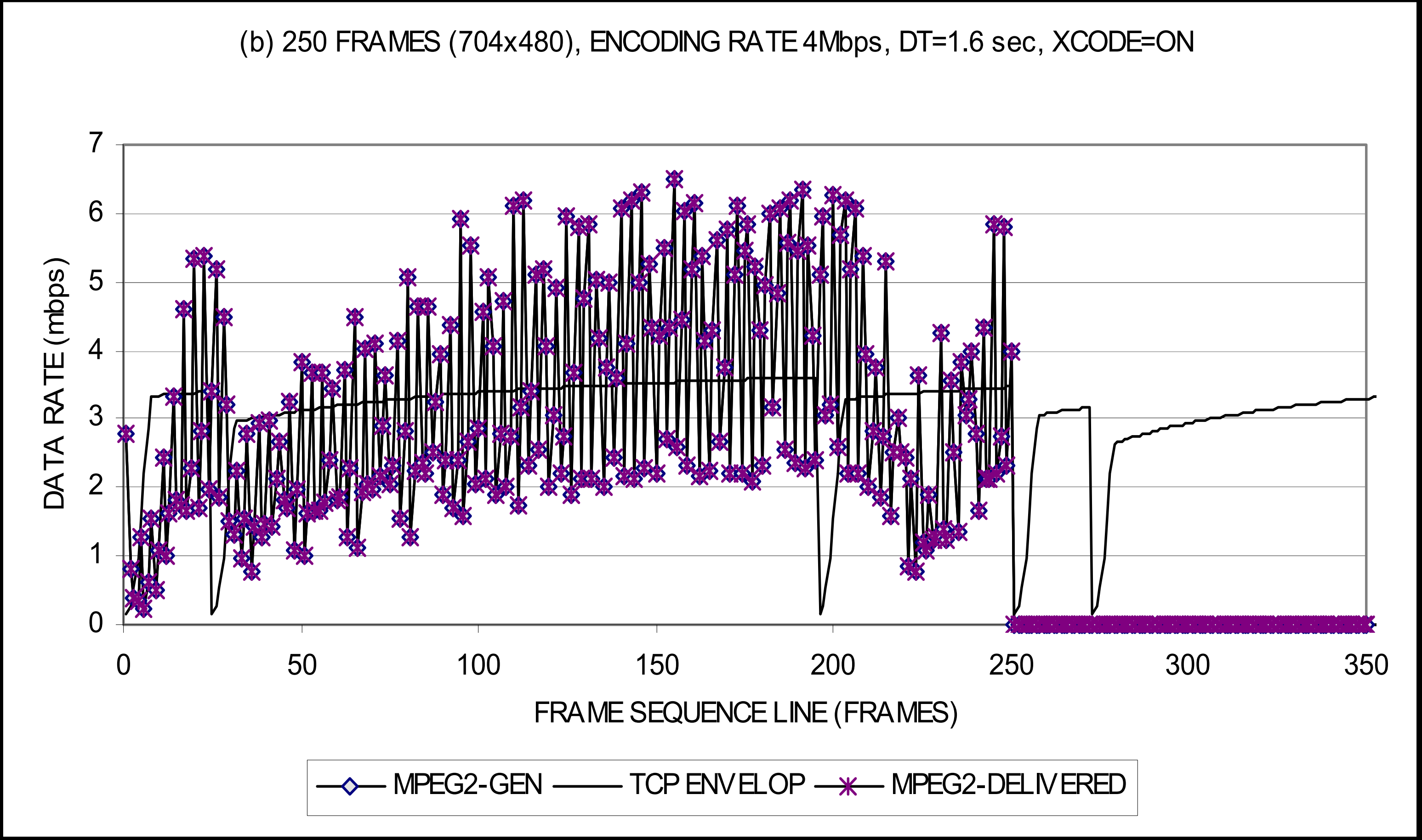
MPEG2 Transport Level Performance (classical TCP)



MPEG2 Transport Level Performance (TCP Interactive)



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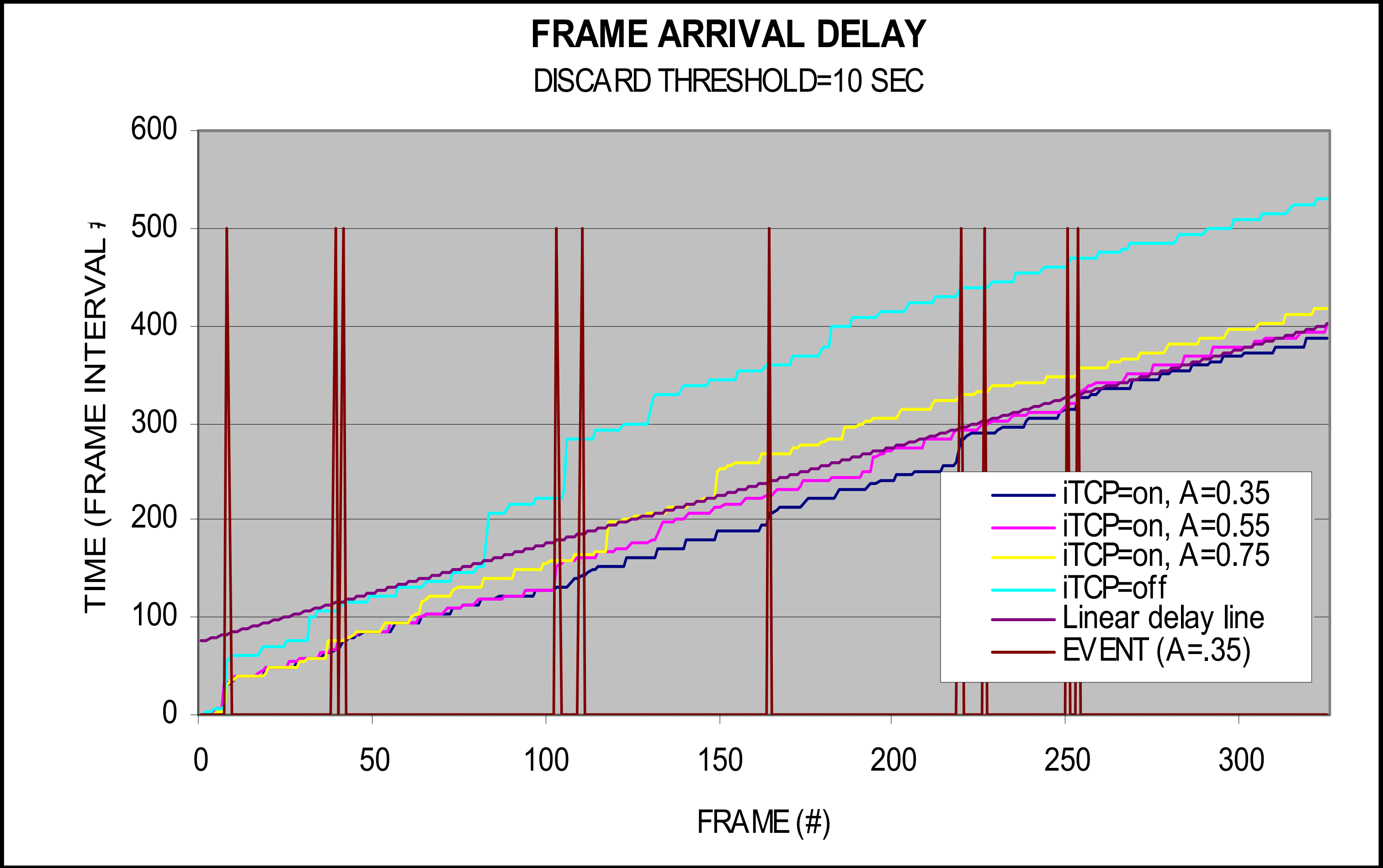
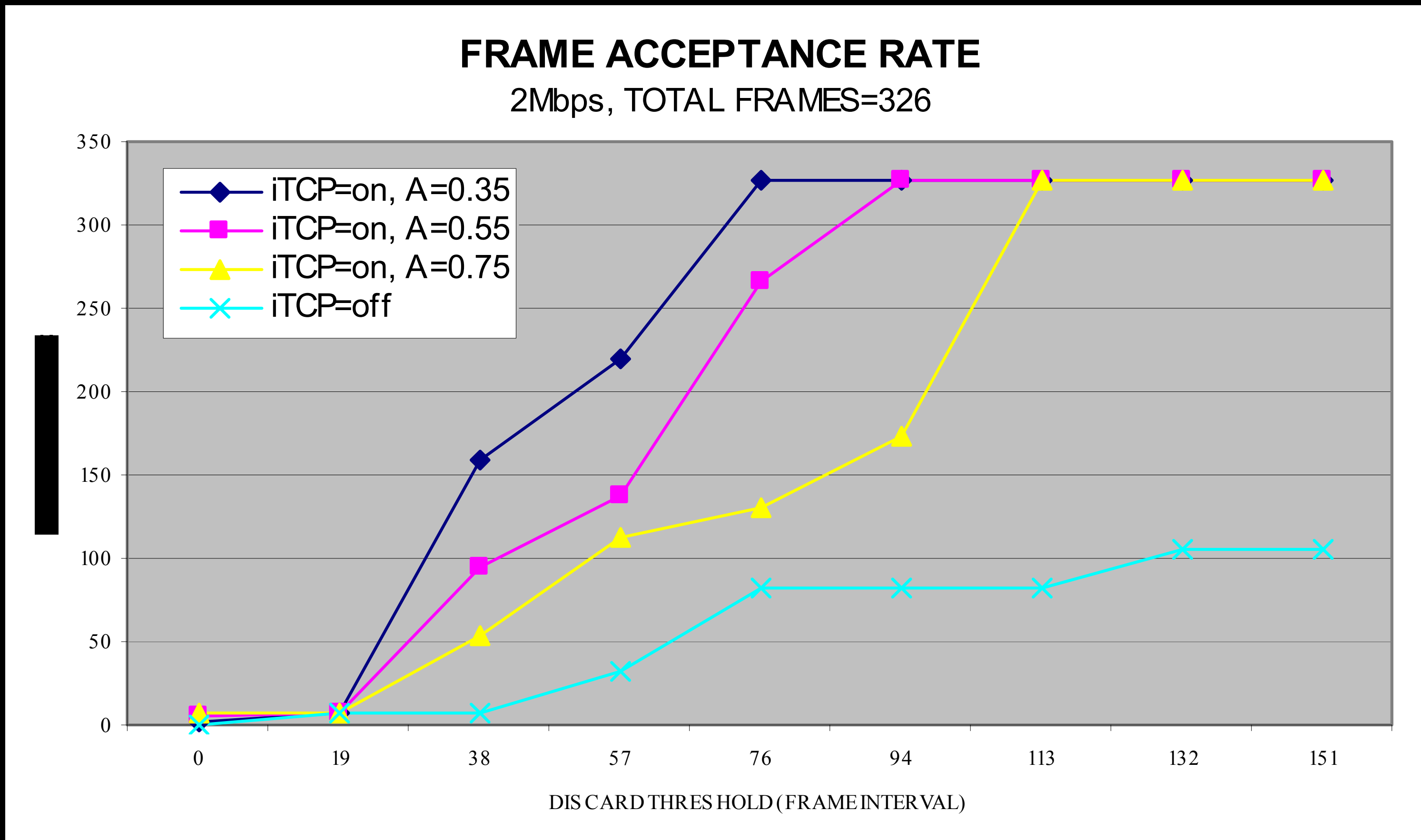
EXPERIMENT-1

(CONTROLLED CONGESTION)

Frame Arrival Delay



Frame Acceptance Rate



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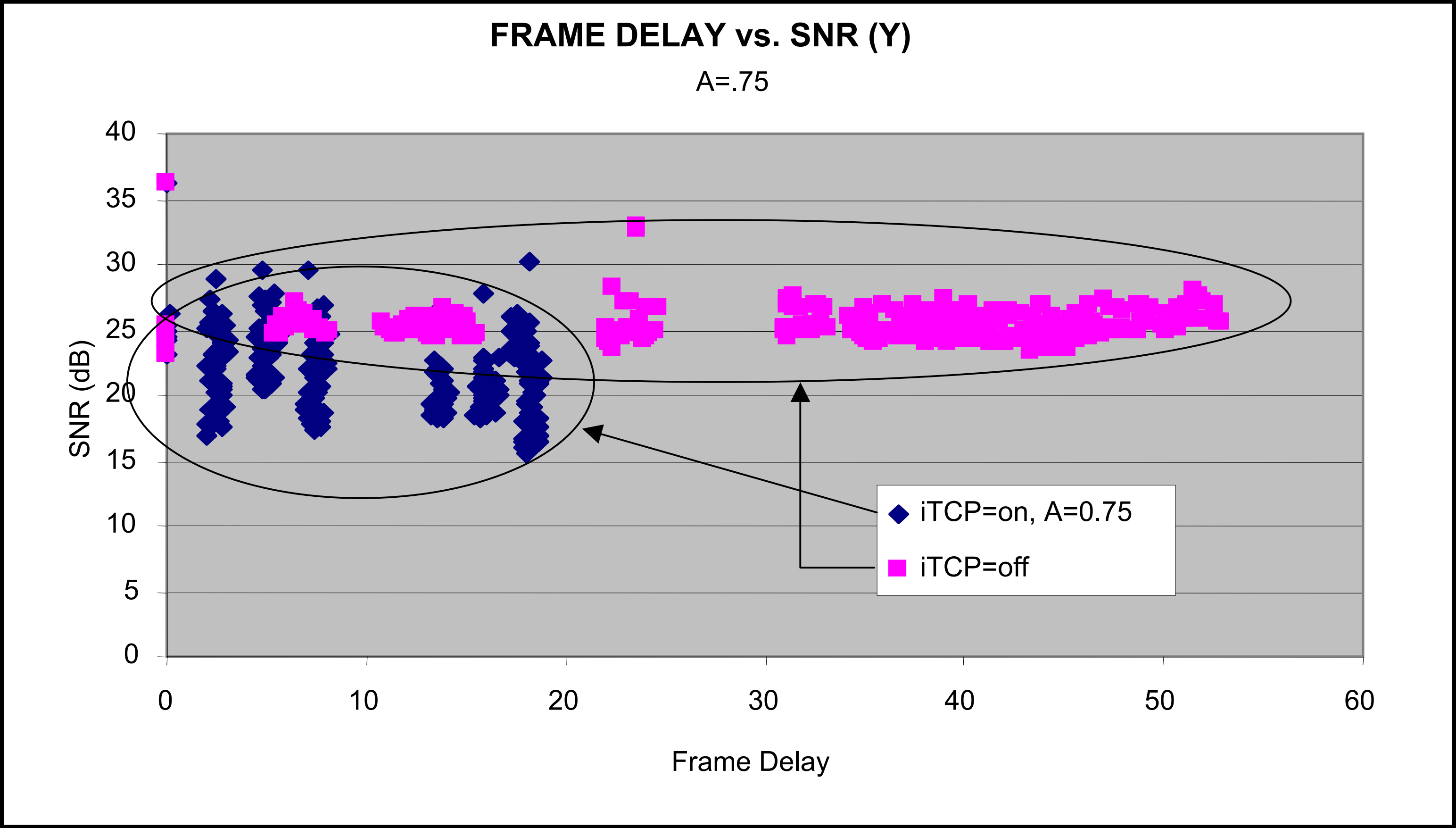
Frame Delay vs. Quality



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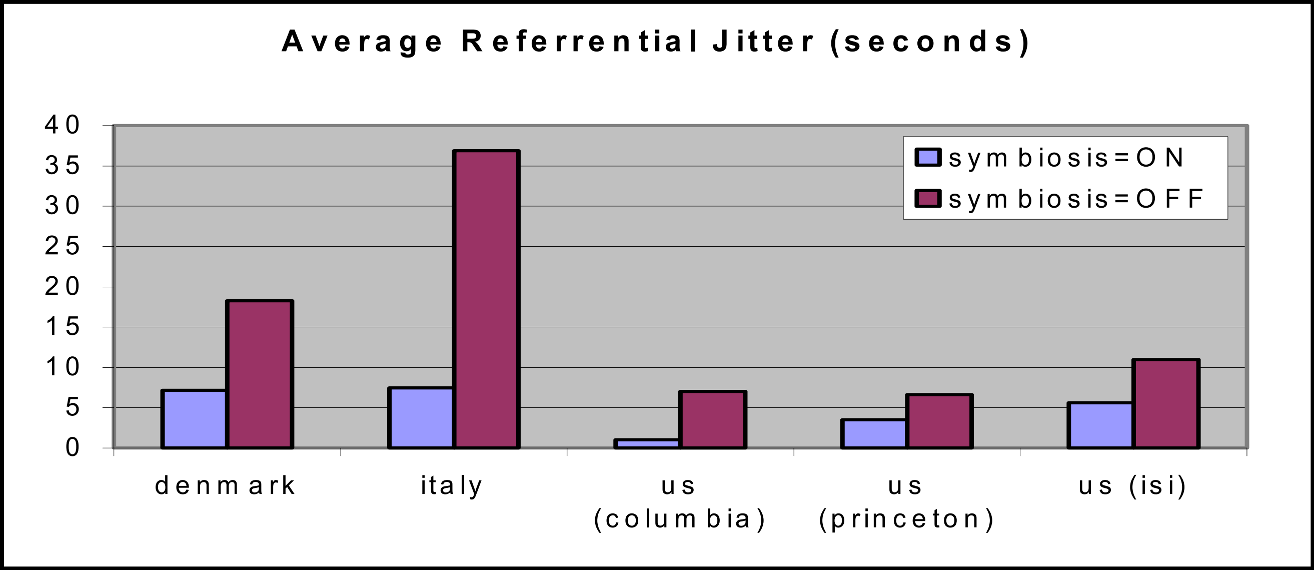
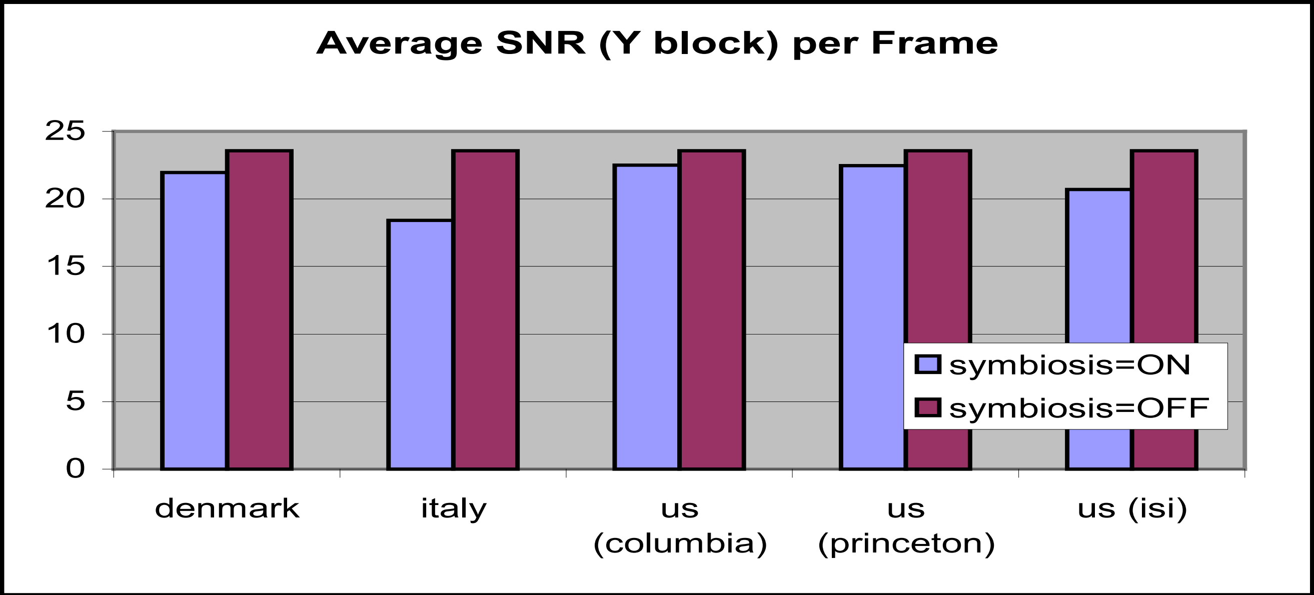
EXPERIMENT-2

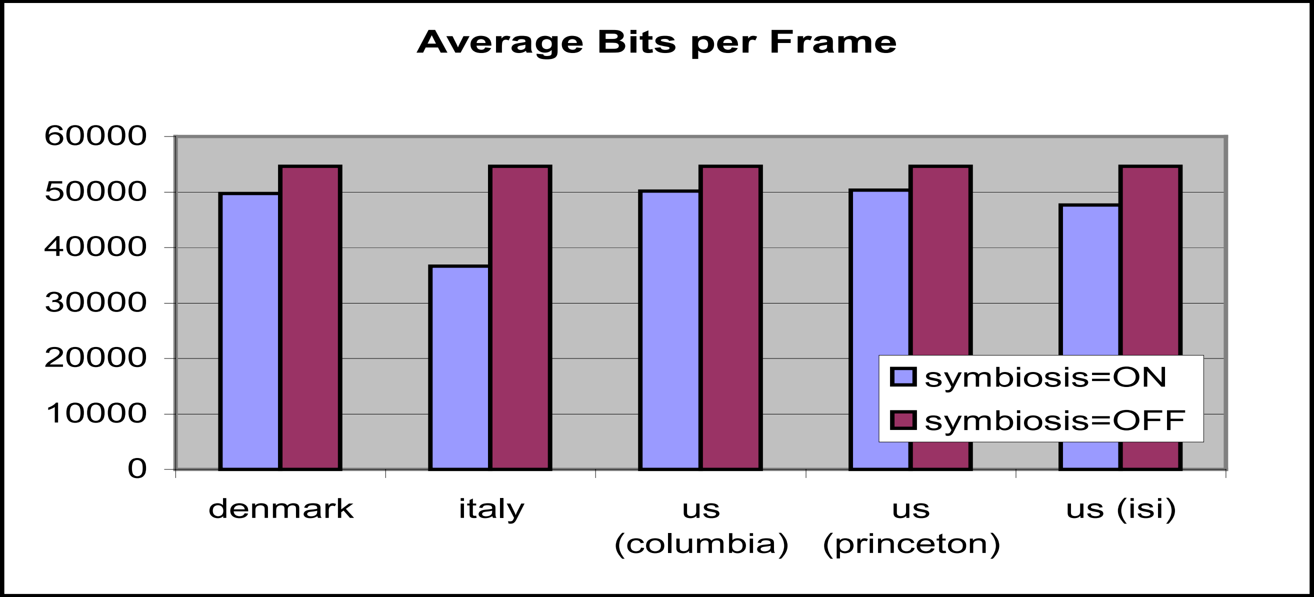
(GLOBAL VIDEO STREAMING OVER ABONE)

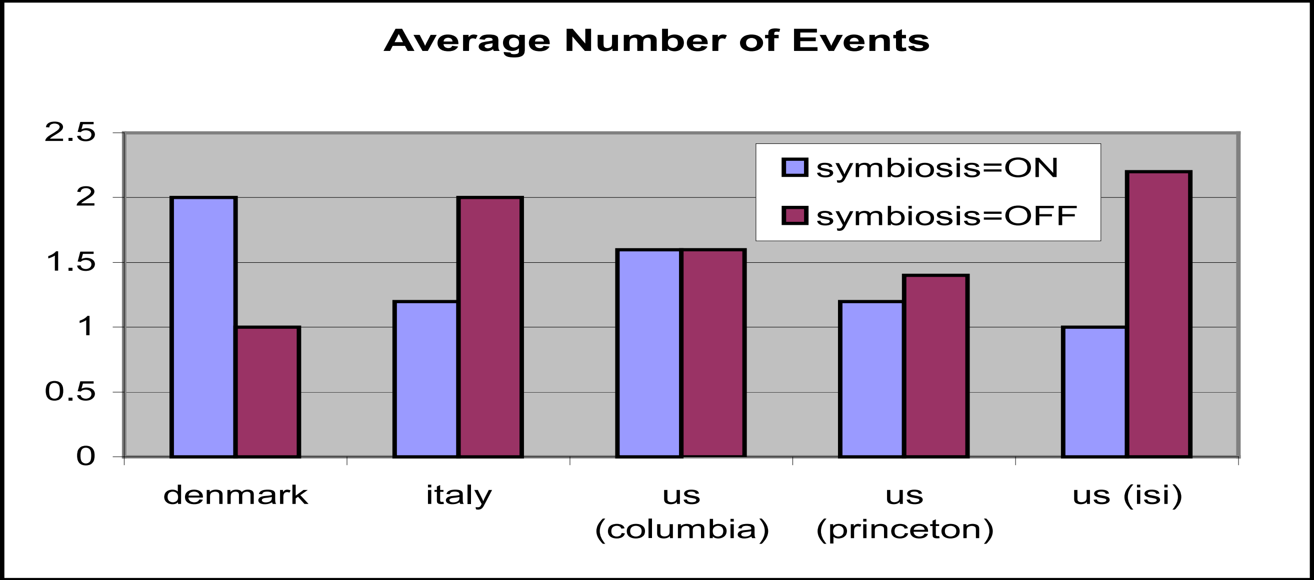
ABone Sites

ABone node	IP	Country	# of Hubs	RTT (ms)		
				Avg	min	max
abone.fokus.gmd.de	193.175.135.49	Denmark	21	144	131	216
galileo.cere.pa.cnr.it	147.163.3.12	Italy	20	287	266	339
abone7.cs.columbia.edu	128.59.22.217	NY, USA	15	41	39	60
abone-01.cs.princeton.edu	128.112.152.62	NJ, USA	15	51	46	69
dad.isi.edu	128.9.160.202	CA, USA	16	65	65	68


Average Referrential Jitter (seconds)
40
35
30
25
20
15
10
5
0
symbiosis=ON
symbiosis=OFF
denmark
italy
us (columbia)
us (princeton)
us (isi)


Average SNR (Y block) per Frame
25
20
15
10
5
0
symbiosis=ON
symbiosis=OFF
denmark
italy
us (columbia)
us (princeton)
us (isi)


Average Bits per Frame
60000
50000
40000
30000
20000
10000
0
denmark
italy
us (columbia)
us (princeton)
us (isi)
symbiosis=ON
symbiosis=OFF


Average Number of Events
2.5
2
1.5
1
0.5
0
denmark
italy
us (columbia)
us (princeton)
us (isi)
symbiosis=ON
symbiosis=OFF

Comments on Symbiotic Congestion Control

Avoidance of Duplicate Effort

- Many proposals are on the table to anyway empower applications by end-to-end measurement.
- data required for optimization is anyway collected by the protocol underneath, why not take the direct solution rather than duplication?

- Complements other congestions avoidance/control techniques without disturbing their underlying mode of operations.

- Not applicable universally. Applicable only where opportunity of rate adaptation exists i.e. “time elastic traffic”.

Comments on Interactive Transport

- Next generation transport for dynamic environment.

- Incremental Interactivity
  - Interactivity has been achieved quite simply just by end-point enhancements of the parties interested. Deployment does not require any grand modification of network protocols.

- Applications: Enables devising of innovative case specific custom solutions to many problems including:
  - Network fault recovery and healing.
  - Temporal QoS provisioning with buffer delay guarantee. (already implemented at KSU)
  - Date error recovery.
  - Dynamic congestion response.
  - Complex Service Composition: Daisy chain Store-and-Forward FTP (already implemented at KSU)

- T-ware Features:
  - Functionally compatible with classical transport-peers.
  - Does not interfere with network dynamics.
  - Legacy compatible for existing applications.
  - Drastically simple at networking layers and intuitive.
  - Transientware is disposable & reusable.

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Additional Information

- A FreeBSD distribution of TCP Interactive is now available from http://medianet.kent.edu/distributions.html

- If you have a transport enhancement need we will be happy to work with you on a T-ware mechanism.

- Published papers on T-ware and technical reports with detail performance is also available from the site. http://medianet.kent.edu/pub.html

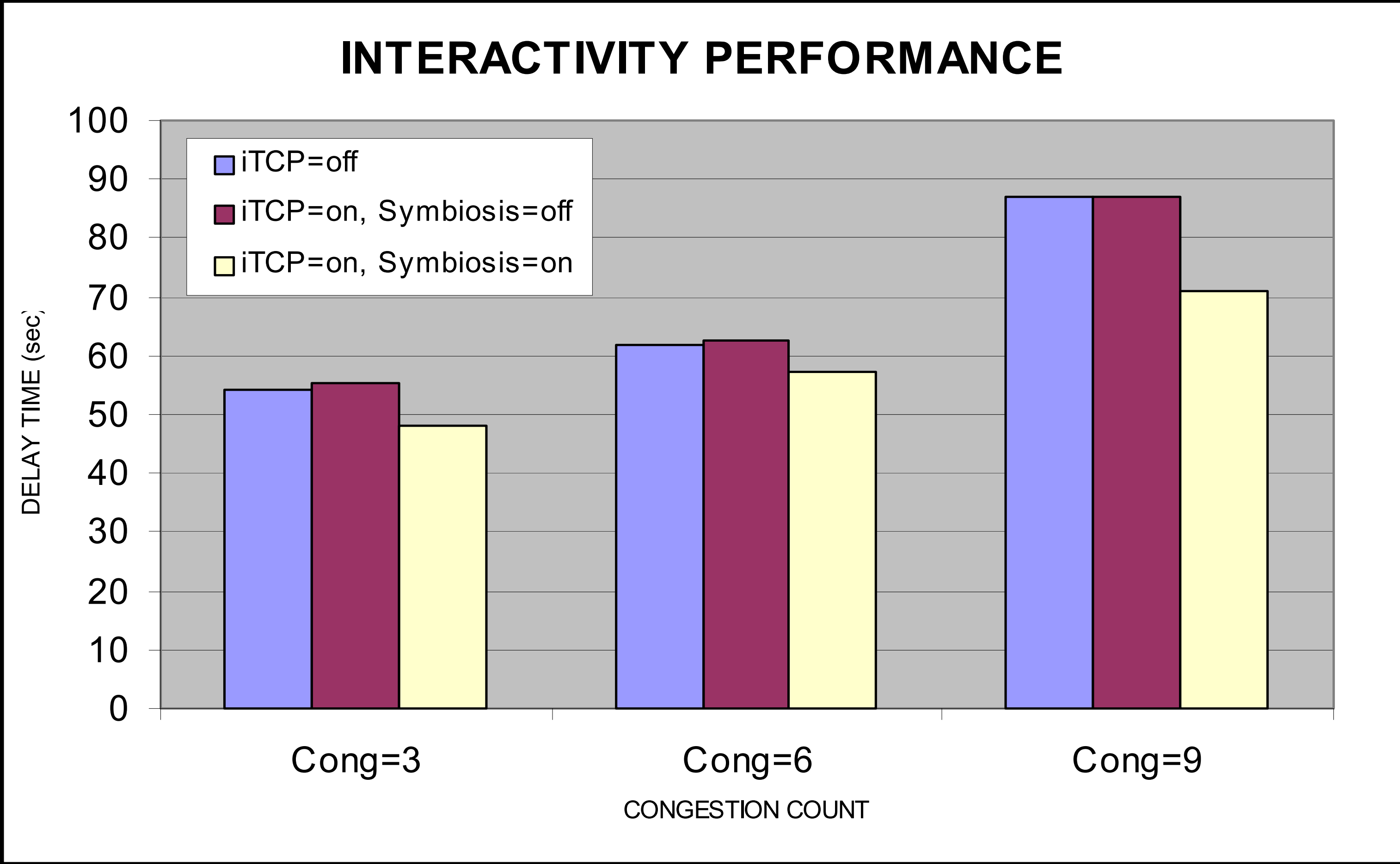
Thanks!

ACK: Supported by DARPA Grant F30602-99-1-0515

EXTRA
EXPERIMENT-3

(Interactivity Overhead)

Overhead of Interactivity



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